SECTION IV. THEORY OF OPERATION

16.4.1 **PRINCIPLES OF OPERATION**

The thunderstorm sensor (figure 16.4.1) consists of three major components contained in the main enclosure:

- Antenna assembly
- Power/Comm module
- Electronics module

The main enclosure is a specially designed, weather-proof box with a hinged and gasket-sealed door held closed with two stainless steel fasteners. When closed, the box is air-tight and water-tight. The main enclosure contains the electronics module and the power/communications module (power/comm module). The electronics module contains the analog board and the processor board. The power/comm module contains the power/comm board, heater, and fiberoptic modem.

The antenna assembly supplies signals to the electronics module which interprets and processes these signals. The power/comm module provides power for the sensor and communications with the outside world.

16.4.2 **SIMPLIFIED BLOCK DIAGRAM DESCRIPTION**

A functional block diagram of the thunderstorm sensor is shown in figure 16.4.2. The thunderstorm sensor consists of an electro-optical antenna assembly, power/comm module , and an electronics module. The antenna assembly detects the electric field signal generated by lightning discharges while the antenna optical sensor detects the associated flash. These two inputs are processed in the electronics module analog board. The main functions of the analog board are:

- Separate noise and lightning signals
- Determine if lightning is “cloud to cloud” or “cloud to ground”
- Estimate range of “cloud to ground” lightning

After these functions are performed, the analog signal is routed to the processor board. The analog board and the processor board are the main components of the electronics module. The processor board performs both analog and digital functions. The analog signals from the analog board are shaped and converted to digital format required by the processor board’s microprocessor circuitry. The following functions are performed by the processor board:

- Convert lightning data into message format for transmission to the ACU, DCP, or SCA
- Store lightning and self-test data and include into reports
- Fiberoptic modem data input/output (I/O) handling
- Microprocessor housekeeping functions

The processor board sends data to the power/comm module, where the data is converted to the RS-232 format and sent to the fiberoptic modem. The power/comm module also provides 12-volt power for the sensor and processes data communications with the DCP (SCA). Each field replaceable unit (FRU) is easily replaced and interchangeable with other thunderstorm sensors.

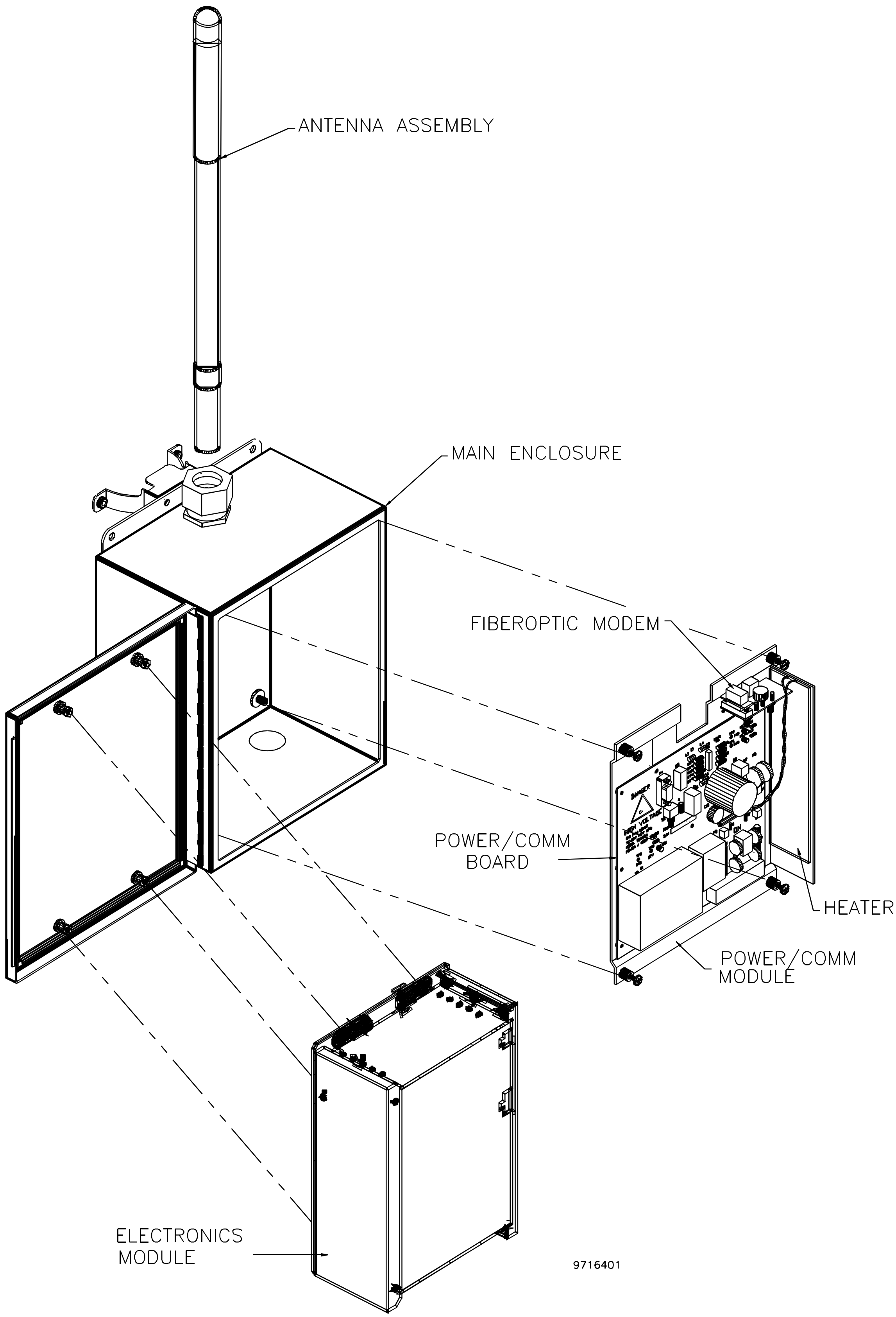

Figure 16.4.1. Thunderstorm Sensor Modules

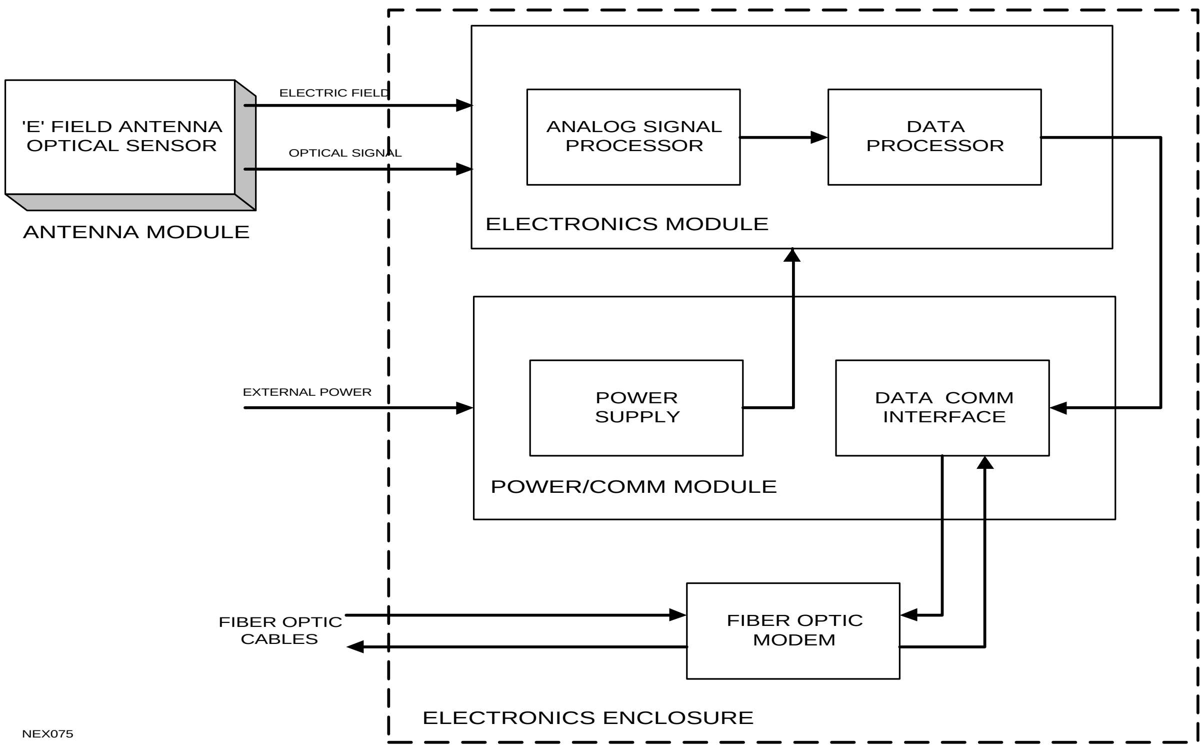

Figure 16.4.2. Functional Block Diagram

16.4.2.1 **Power and Power Supplies**. Power is supplied to all circuitry by a linear, 12 VDC power supply. AC power is brought on to the power/comm module where it is fused, switched, over-voltage limited, and filtered before being passed to the power supply. The regulated 12 VDC output is supplied to the circuitry where additional regulation to other power supply voltages is performed. The power/comm module also manages the power for the heater. Power is supplied to the heater by a separate AC circuit on the power/comm module that is switched in common with the main circuit power. AC for the heater is passed through a full-wave rectifier, filtered, current limited, and supplied to a heating element through a thermostat mounted to the power/comm module. Inrush current limiters are used in the heater circuit to slow the turn-on transient of the heater.

16.4.2.2 **Communications**. The power/comm module also handles data communications to the outside world. TTL level transmit and receive data signals are converted to RS-232 levels on the power/comm module. RS-232 level data lines are passed to the fiberoptic modem.

16.4.2.3 **Self-tests**. Given a healthy sensor in a normal sensor site, failed self-tests are rare. An occasional failed self-test does not necessarily indicate a defective unit. Occasionally, a self-test fails because of external interference.

The self-test exercises the majority of the circuitry in the sensor. Every 30 minutes and upon command from a host computer or terminal, the sensor injects simulated lightning signals into the electric field channel and simultaneously injects a simulated lightning light pulse into the optical sensor. These signals are acted upon by circuitry on the analog board and processor board in the electronics module and a self-test result is generated. The processor board keeps track of a bit that indicates that the signal in process is from a self-test and not from natural lightning.

The sensor reports that a self-test has failed only after successive failed self-tests, not on a single failed self-test (which can occur in normal sites with a healthy sensor due to transient, external noise interference). When the sensor fails a single self-test, it repeats the self-test four times. The self-test result reported is the majority value of the results of the five self-tests. After the sensor reports a failed self-test, it does not continue to report lightning.

If the sensor is unable to perform a self-test, it tries four more times (as with a failed self-test). If unsuccessful after five attempts, the sensor reports a failed self-test and puts the sensor in the DOWN state. Due to an approximate 2-second time-out, the total delay from the time a self-test is requested until a response is received may be 10-14 seconds if a self-test cannot be performed on all five attempts. In the DOWN state, the sensor will attempt to do a self-test once each minute. After the sensor reports a failed self-test, it does not continue to report lightning.

16.4.2.4 **Lightning Categories**. The sensor detects two types of lightning: cloud-to-cloud and cloud-to-ground (CG) lightning. CG lightning is further categorized according to its range. As set at the factory, CG lightning within zero to five miles of the sensor is categorized as Overhead, lightning within five to ten miles is categorized as Near, and lightning within ten to thirty miles is categorized as Distant.

16.4.2.5 **Processing Strokes and Flashes**. A CG lightning discharge is actually made up of one or more individual discharges occurring in rapid succession. The total CG discharge is called a flash. Each individual discharge within a flash is called a stroke.

The sensor detects individual lightning strokes. The sensor groups stroke messages into flashes. All stroke messages received within one second of the first stroke message are considered to be part of a single flash. A flash counter is increased by one for each flash detected, regardless of the number of stroke messages that were received within one second of the first stroke of the flash.

The sensor reports the range of a flash as the range of the nearest stroke in that flash. Signals from different CG discharges that occur at nearly the same time may occasionally be grouped together and counted as one flash. Cloud discharges that occur during the one-second period for flash grouping are not considered part of the CG discharge.

The algorithm used in the sensor for processing bursts of lightning stroke data was designed to identify and classify lightning in much the same way that a diligent, omniscient human lightning observer would.

16.4.2.6 **Signal Processing**. The sensor antenna responds to changes in the electric field and to optical impulses. The electronics module inside the sensor processes both of these signals in order to determine if they were caused by lightning. If so, the signals are further processed to determine whether their source was a cloud or a CG discharge. If the signals were caused by CG lightning, additional processing determines the approximate range and polarity of the lightning.

All of the functions listed above are provided by fast, low-power analog signal processing circuitry on the analog board and pulse-shape logic on the processor board.

The data about each stroke of each lightning flash is supplied to the microcontroller portion of the processor board where the following functions are performed:

- Stroke data messages are sorted into sensible flash counts.
- Flash counts are aged.
- All data I/O is handled.
- Housekeeping functions (self-test, error counting, and history accounting) are performed.

16.4.3 **COMMAND DESCRIPTION**

16.4.3.1 **Host Mode**. The thunderstorm sensor host mode uses two-way (duplex) communications with a laptop computer connected to the sensor (refer to Section V). Host mode is enabled when switch 6 of SW101 is Down. Table 16.4.1 shows the requests or commands that a host computer can send to the sensor. These requests are made by sending a single, upper-case, ASCII character to the sensor. The Host mode commands are further described in the following paragraphs.

Table 16.4.1. Host Command Set

ASCII Character	Function
A	Send a present Weather Message
B	Send a Status message
C	Perform a Self-Test
D	Perform a Reset
E	Perform a Type Test
F	Send system Run Time
G	Send Version Message

16.4.3.2 **Send Present Weather Message**. When the host computer issues the ASCII character A to the sensor in the Host mode, the sensor sends a present weather message with flash count and status information as shown in table 16.4.2.

Table 16.4.2. Response to Command A: Present Weather Message

Byte	Description	Value
1	Overhead flash counts label	O
2-6	Overhead flash counts	0-29999
7	Near flash counts label	N
8-12	Near flash counts	0-29999
13	Distant flash counts label	D
14-18	Distant flash counts	0-29999
19	Cloud flash counts label	C
20-24	Cloud flash counts	0-29999
25	Total flash counts label	T
26-30	Total flash counts	0-29999
31	Self-test results: P = passed F = failed ? = no self-test performed	P F ?
32-33	Status byte (see section 5.2.5.3.1)	00-FF
34	Hex radix delimiter	H
35	Carriage return	<CR>
36	Line feed	<LF>
C Format String `"O%5uN%5uD%5uC%5uT%5u%c%2xH\n"`		
Example: `O 7N 1D 2C 2T 12PC6H<CR><LF>`		

16.4.3.3 **Send Status Message**. By sending the ASCII character B, the host may request from the sensor a status message that consists of accumulated status, flash, and stroke counts. The accumulated counts are strictly for diagnostic purposes as they do not reflect the current storm counts, but rather the history of lightning counts and housekeeping information. The history accumulates during a cycle of the sensor's internal clock. When the sensor is powered up or reset, the internal clock is started; the clock rolls over every 24 hours. The status message counts are cleared (set to zero) at power-up, reset, and normally at rollover of the 24-hour clock. The status message format is described in table 16.4.3.

If switch 7 on SW101 is Down, the status message is not cleared at clock rollover; counts will accumulate until the sensor is reset or powered up.

Table 16.4.3. Response to Command B: Status Message

Line	Byte	Description	Value
1	1	Overhead flashes label	O
	2-6	Overhead flashes	0-29999
	7	Near flashes label	N
	8-12	Near flashes	0-29999
	13	Distant flashes label	D
	14-18	Distant flashes	0-29999
	19	Cloud flashes label	C
	20-24	Cloud flashes	0-29999
	25	Total flashes label	T
	26-30	Total flashes	0-29999
	31	Carriage return	<CR>
	32	Line feed	<LF>
2	33	Overhead strokes label	o
	34-38	Overhead strokes	0-29999
	39	Near strokes label	n
	40-44	Near strokes	0-29999
	45	Distant strokes label	d
	46-50	Distant strokes	0-29999
	51	Cloud strokes label	c
	52-56	Cloud strokes	0-2999
	57	Total strokes label	t
	58-62	Total strokes	0-29999
	63	Carriage return	<CR>
	64	Line feed	<LF>
3	65	Passed self-tests label	p
	66-70	Passed self-tests	0-29999
	71	Failed self-tests label	f
	72-76	Failed self-tests	0-29999
	77	Lost real strokes label	l
	78-82	Lost real strokes	0-29999
	83	Lost simulated strokes label	l
	84-88	Lost simulated strokes	0-29999
	89	Total of row label	t
	90-94	Total of row	0-29999
	95	Carriage return	<CR>
	96	Line feed	<LF>

C Format String:
```
"O%5uN%5uD%5uC%5uT%5u\n"
"o%5un%5ud%5uc%5ut%5u\n"
"p%5uf%5ul%5ul%5ut%5u\n"
```

Example:
```
O   7N   1D   2C   2T   12<CR><LF>
o  35n   1d   7c   2t   45<CR><LF>
p  16f   0l   0l   0t   16<CR><LF>
```

16.4.3.4 **Perform Self-test**. The sensor performs a self-test every 30 minutes; the status byte in the Present Weather message indicates the results of the most recent self-test. The host computer may initiate a self-test at any time by sending the ASCII character C to the sensor. The results of the self-test are described in table 16.4.4.

Table 16.4.4. Response to Command C: Self-test Message

Byte	Description	Value
1	Self-test result P = passed F = failed ? = no self-test performed	P F ?
2-3	Status byte (see section 5.2.5.3.1)	00-FF
4	Hex radix delimiter	H
5	Carriage return	<CR>
6	Line feed	<LF>
C Format String: "%c%2xH\n"		
Example: PC6H<CR><LF>		

Self-test commands that are issued too frequently may interfere with the reception of natural lightning signals. If a natural lightning signal is “in process” at the time that a self-test command is issued, the sensor completes the processing of the natural lightning signal.

The self-test may fail during a thunderstorm because of high levels of background noise. Therefore, self-test results should be ignored during thunderstorms until all lightning counts have aged out of the count fields. The host computer must monitor and make decisions about the status byte that is shown in the present weather message.

16.4.3.4.1 **Self-test Status Byte**. The eight-bit status byte gives information about the state of the electronics and power supplies in the sensor. The status byte, contained in the response to the ASCII character C, can be scanned for diagnostic information about the sensor as shown in table 16.4.5.

Table 16.4.5. Self-test Status Byte

7	6	5	4	3	2	1	0	Bit
								0: Input voltage greater than approximately 11V 1: Input voltage less than approximately 11V, analog board shutdown
								0: Input voltage greater than approximately 13V 1: Input voltage less than approximately 13V
								0: Sensor is in reset mode 1: Sensor is running
								0: Sensor is ready for lightning 1: A stroke is being processed
								0: 5V supply OK 1: 5V supply low
								0: 10V supply OK 1: 10V supply low
								1: Always 1
								1: Always 1

16.4.3.5 **Perform Reset**. Turning power on and off resets the sensor. As an alternative, the host computer may issue a reset command (the ASCII character D) to cause the sensor to reset (CPU and hardware). Because this command resets the sensor, no serial response is issued from the sensor. Other than for EPROM program storage and DIP switches for option selection, there is no nonvolatile memory in the sensor.

16.4.3.6 **Perform Type Test**. A type test has been included in the Host mode command set to allow troubleshooting of communications links. The type test is initiated by sending the ASCII character E to the sensor. The type test output is shown in table 16.4.6.

Table 16.4.6. Response to Command E: Type Test Output

Byte	Description	Value
1-37	Test string	ABCDEFGHIJKLMNOPQRSTUVWXYZ O123456789
38	Carriage return	<CR>
39	Line feed	<LF>
C Format String: `"ABCDEFGHIJKLMNOPQRSTUVWXYZ 0123456789\n"`		
Example: `ABCDEFGHIJKLMNOPQRSTUVWXYZ 0123456789<CR><LF>`		

16.4.3.7 **Send System Run Time**. The sensor has a system clock which indicates the length of time the sensor firmware has been running. The system clock message, described in table 16.4.7, is sent when the ASCII character F is sent to the sensor by the host.

Table 16.4.7. Response to Command F: System Run Time Message

Byte	Description	Value
1	Days label	D
2-4	Days	0-999
5	Hours label	H
6-7	Hours	0-24
8	Minutes label	M
9-10	Minutes	0-59
11	Seconds label	S
12-13	Seconds	0-59
14	Carriage return	<CR>
15	Line feed	<LF>
C Format String: `"D%3uH%2uM%2uS%2U\n"`		
Example: `D   0H  1M26S 6<CR><LF>`		

16.4.4 DIAGNOSTIC TESTS

Using SW100, the user may select diagnostic tests, units of measure for ground discharge range estimates, and the aging interval. The switch settings in SW100 for diagnostic tests are shown in table 16.4.8. The diagnostic tests are further described in the following paragraphs. Once a diagnostic has been entered, the only way to exit the diagnostic is to change the switches and reset the sensor.

Table 16.4.8. SW100 Switches 1-3: Diagnostic Tests

SW100			Diagnostic Test
1	**2**	**3**	
Up	Up	Up	Normal operation
Up	Up	Down	Self-test @ 1 per second
Up	Down	Up	Echo test
Up	Down	Down	Watchdog timer test
Down	Up	Up	Switch test
Down	Up	Down	Type test
Down	Down	Up	Reserved
Down	Down	Down	Reserved

16.4.4.1 **Self-test**. The self-test diagnostic (switch 1 Up, switch 2 Up, and switch 3 Down on SW100) causes a self-test to occur once per second. Self-test results are transmitted (in hex) every second, one result per line. Note that there are certain sensor failure modes that prevent it from performing a self-test.

16.4.4.2 **Echo Test**. The echo test (switch 1 Up, switch 2 Down, and switch 3 Up on SW100) continuously polls the receiver of the serial port for input from the attached terminal or computer. In the echo test, every character sent to the sensor is sent back (retransmitted or "echoed") to the terminal, and carriage returns are expanded to a carriage return/line feed. Since there are no spaces inserted between echoed characters, what is typed is what is echoed. The echo test may be useful for troubleshooting problems with data communications links.

16.4.4.3 **Watchdog Timer Test**. To prevent the CPU from remaining in a hung-up or non-running condition, a timer (referred to as the watchdog timer) is implemented in the hardware to periodically issue a reset to the CPU. The watchdog timer test (switch 1 Up, switch 2 Down, and switch 3 Down on SW100) puts the CPU into an idle state that allows the watchdog timer to reset it. Failure of this test implicates the watchdog timer function of the CPU on the processor board.

16.4.4.4 **Switch Test**. The switch test (switch 1 Down, switch 2 Up, and switch 3 Up on SW100) continuously reads each of the switches in SW101 and SW100 and displays their values in hex each time they change. This test also causes the status byte to be read and output.

16.4.4.5 **Type Test**. The type test (switch 1 Down, switch 2 Up, and switch 3 Down on SW100) causes a continuous string of alphanumeric characters to be sent out the serial port. The type test is useful for checking out communications links between the sensor and the host computer, data terminal, or data collection platform. Because there is no delay inserted between transmissions, slow computers may experience buffering problems with this test.